

## I CLAIM:

- 1           1. A rotary tool for drilling into a soil formation from  
2           its surface, controllably injecting water and binder at known  
3           depths below the surface of said formation, and mixing said soil,  
4           water and binder to form an in-situ piling, said tool comprising:  
5                 a rotary shaft having a central axis of rotation  
6                 adapted to be driven bi-directionally around said axis, and bi-  
7                 directionally along said axis;  
8                 a vane on and extending radially from said shaft to be  
9                 rotated around and moved axially by said shaft, said vane being  
10                so disposed and arranged as to move through the formation along a  
11                helical path to drill into said formation, to stir the material  
12                of the formation, and ultimately to mix the material of the  
13                formation with water and binder;  
14                a water injector and a binder injector carried by said  
15                tool, each injector having a respective axis of emission of water  
16                or of binder, said axes of emission being directed away from said  
17                tool into said formation at a respective location along said  
18                central axis;  
19                said injectors being so disposed and arranged relative  
20                to one another that the material of their emissions will during a  
21                limited number of revolutions of said shaft, encounter one  
22                another, then to be mixed as a pre-determined ratio of water and  
23                of binder, said water including water emitted from the water

24 injector and water which may have already been present at that  
25 location.

1           2. A rotary tool according to claim 1 in which said  
2 injectors are set in said shaft with their axes of emission  
3 substantially normal to said central axis, and located along said  
4 central axis such that the emission of one of them will, within a  
5 limited number or rotations of the shaft encounter and mix with  
6 the other in a temporally suitable time related to the curing of  
7 the binder and drainage of the water.

1           3. A rotary tool according to claim 2 in which said  
2 injectors are disposed about 180 degrees apart as viewed in  
3 lateral section.

1           4. A rotary tool according to claim 1 in which the said  
2 water injector and binder injector are provided as a pair, their  
3 axes of emission intersecting adjacent to said shaft under in-  
4 situ pressure whereby to produce a mixture of water and of binder  
5 with a velocity having a radial component of motion.

1           5. A rotary tool according to claim 1 in which said binder  
2 injector is surrounded by a plurality of water injectors, the  
3 axes of emission of said water injectors intersecting the axis of

4 emission of the binder injector

1 6. A rotary tool according to claim 1 in which said  
2 injectors are set in said vane at a radial distance from said  
3 shaft.

1 7. A rotary tool according to claim 6 in which the said  
2 water injector and binder injector are provided as a pair, their  
3 axes of emission intersecting adjacent to said shaft under in-  
4 situ pressure whereby to produce a mixture of water and of binder  
5 with a velocity having a radial component.

1 8. A rotary tool according to claim 2 in which a pair of  
2 said water injectors and at least one of said binder injectors  
3 are set in said shaft, with said binder injector located axially  
4 between said water injectors.

1 9. A rotary tool according to claim 2 in which a pair of  
2 said binder injectors and at least one of said water injectors  
3 are set in said shaft, with said water injectors located axially  
4 between said binder injectors.

1 10. In combination:  
2 a rotary tool according to claim 1; and

3        a control valve respective to each of said injectors,  
4        whereby the rate of supply of water and of binder can  
5        independently be regulated by said control valve to provide  
6        binder at a rate desired at a respective depth and water at a  
7        rate desired which with existing water already in the formation  
8        at that depth, will constitute at least sufficient water for  
9        stoichiometric reaction of the binder.

1        11.    A combination according to claim 10 in which a program  
2        controls said control valves to establish the rates of supply of  
3        the binder and the water.

1        12.    A combination according to claim 11 in which said rates  
2        are related to already known water conditions and binder  
3        requirements at respective depths below said surface.

1        13.    A combination according to claim 11 in which said rates  
2        are related to water conditions sensed at depths below said  
3        surface.

1        14.    A combination according to claim 10 in which said  
2        injectors are set in said shaft with their axes of emission  
3        substantially normal to said central axis, and located along said  
4        central axis such that the emission of one of them will, within a

5 limited number or rotations of the rotary tool encounter and mix  
6 with the other in a temporally suitable time related to the  
7 curing of the binder and drainage of the water.

1 15. A combination according to claim 10 in which the said  
2 water injector and binder injector are provided as a pair, their  
3 axes of emission intersecting adjacent to said shaft under in-  
4 situ pressure whereby to produce a mixture of water and of binder  
5 with a velocity having a radial component of motion.

1 16. A combination according to claim 10 in which said binder  
2 injector is surrounded by a plurality of water injectors, the  
3 axes of emission of said water injectors intersecting the axis of  
4 emission of the binder injector.

1 17. A combination according to claim 10 in which said  
2 injectors are set in said vane at a radial distance from said  
3 shaft.

1 18. A combination according to claim 10 in which a pair of  
2 said binder injectors and at least one of said water injectors  
3 are set in said shaft, with said water injectors located axially  
4 between said binder injectors.

1        19.    Apparatus according to claim 1 in which a baffle is  
2        fixed to each said vane to confine emissions from said injectors  
3        to the region encountered by said vanes.

1        20.    The method of forming an in-situ piling in a soil  
2        formation with binder and sufficient water to produce a  
3        stoichiometrically correct mixture, comprising:

4                with a rotary tool, drilling into said formation, said  
5        tool having a rotary shaft that has a central axis of rotation  
6        and a vane for drilling into and mixing the soil, rotated around  
7        and moved axially by said shaft, said vane being so disposed and  
8        arranged as to move through the formation along a helical path to  
9        drill into said formation, to stir the material of the formation,  
10       and ultimately to mix the material of the formation with water  
11       and binder;

12               a water injector and a binder injector carried by said  
13       tool;

14               driving said tool axially into and out of said  
15       formation while rotating it;

16               at some times during axial movement of said tool,  
17       discharging water or binder from a respective injector into said  
18       soil formation along a respective axis of emission of water or of  
19       binder, said axes of emission being directed away from said tool  
20       into said formation at a respective location along said central

21 axis, so that the material of their emissions will during a  
22 limited number of revolutions of said shaft encounter one  
23 another, there to be mixed as a pre-determined ratio of water and  
24 of binder, said water including water emitted from the water  
25 injector and water which may have already been present at that  
26 depth.

1 21. The method of claim 20 in which injection of binder is  
2 made during passage of said tool into said soil formation.

1 22. The method of claim 20 in which injection of binder is  
2 made during passage of said tool out of said soil formation.

1 23. The method of claim 20 in which injection of water is  
2 made during passage of said tool into said soil formation.

1 24. The method of claim 20 in which injection of water is  
2 made during passage of said tool out of said soil formation.

1 25. The method of claim 20 in which the emissions of said  
2 injectors intersect adjacent to said shaft.

1 26. The method of claim 20 in which the emission of one of  
2 said injectors is encountered in said soil formation in a

3 temporally suitable time related to the curing of the binder and  
4 drainage of the water.

1 27. The method of claim 20 in which the emission of water  
2 id determined by a program responsive to data from a  
3 representative core.

1 28. The method of claim 20 in which the emission of water  
2 is determined by a program responsive to data relating to water  
3 content already in the soil derived from a sensor on said tool  
4 disposed at an axial location below the place of injection of  
5 said binder.

1 29. The method of claim 20 in which the pressure of the  
2 stream of water and of the binder in the tool is above the  
3 ambient pressure which exists in the formation.